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U. S. DEPARTMENT OF AGRICULTURE.
BOTANICAL DIVISION,

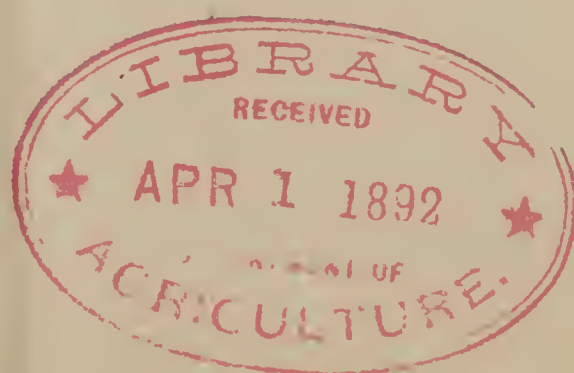
Section of Vegetable Pathology—Circular No. 5.

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FUNGICIDES, OR REMEDIES FOR PLANT DISEASES.

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This circular has been prepared for the use of Directors of Agricultural Experiment Stations and others who may be interested in the treatment of the fungus diseases of plants. The queries of many correspondents of the Department are answered in its contents.

NORMAN J. COLMAN,

Commissioner of Agriculture.



SIR: I submit herewith a circular on fungicides, prepared in accordance with your instructions.

Respectfully,

F. LAMSON SCRIBNER.

Hon. NORMAN J. COLMAN,
Commissioner of Agriculture.

FUNGICIDES.

INTRODUCTORY.

In combating the various fungus diseases of plants many chemicals and chemical compounds have been tried from time to time, and not a few nostrums of the quack order have been widely advertised for this or that, or for every distemper that plants are heir to. A little knowledge of vegetable anatomy and of the character and habits of the fungi to be treated would enable us to avoid the impositions of quacks and assist us in determining the *rationale* of any proposed treatment. The diseases in plants caused by fungi are simply the effects produced by other plants of parasitic habits, and we must keep the two—the parasite and the plant attacked—distinct in our minds in our efforts to protect the one from the evils produced by the other.

For some of these so-called diseases there is no remedy but the knife or the complete destruction of the infested plant. It is important to understand the cases of this character, not only that we may avoid wasting time and money in vain efforts to treat them otherwise, but in order that prompt action may be taken and sources of infection be quickly destroyed, for all fungus diseases may be regarded as infectious. A large class of these diseases, many occasioning heavy annual losses, may be mitigated or entirely overcome by the application of certain remedial or preventive agents. Those remedies or preventives which have apparently yielded positive results are here enumerated, together

with directions for their preparation, mention also being made of the diseases for which they have been employed.

APPLYING THE REMEDIES.

In applying the remedies we must consider the period and manner of the attack made by the parasite and the manner of action of the substance applied. Fungi living within the tissues of the host must be prevented from gaining an entrance to these tissues; fungi which live upon the surface of plants or having their bodies soon exposed through the breaking up of the epidermis, like the apple-scab fungus or the fungus of bird's-eye rot of grapes, may be treated by curative methods. The compounds having sulphate of copper for a base are, so far as we know to-day, the best preventive remedies; sulphur, sulphur and lime, sulphide of potassium, hyposulphite of soda, are to be classed as curatives.

Destructive treatments are available between the periods of vegetation (winter season), and consist in destroying all infectious material and in washing the plants to be protected with strong caustic solutions, *e. g.*, solutions of sulphate of iron or copper and sulphuric acid.

During the growing season the strength of the solutions used is governed by the power of the green tissues to resist their action. In the early part of the season while the shoots and leaves are yet tender, weaker solutions than those which may safely be applied later in the season, must be employed. There is great diversity of susceptibility to the caustic action of the remedies between different species of plants and even between different varieties of the same species. The conditions of the weather at the time the applications are made may be of importance in this connection. Sulphur alone, applied when the weather is very hot and the sun bright, may cause a burning of the foliage. The same is true of sulphatine and also of eau celeste.

Explicit directions can not be given for these cases. Much has yet to be learned by experiment, and each one must exercise judgment and govern himself by surrounding circumstances.

Avoid making the applications excessive; do not drench the plants with the fluids nor plaster them with the powders. With a suitable spraying apparatus, which projects a fine, mist-like spray, merely wet the plant surfaces, and employ bellows which will discharge the powder evenly and in such a manner that the plants may be enveloped in a cloud of dust, which, settling upon all parts, becomes just perceptible.

The necessity for good and easily-worked spraying pumps and bellows is evident. For small plantations and general vineyard use, the knapsack form of sprayer, having the reservoir and pump combined, to be carried on the back of the operator like a knapsack, is the best. For spraying fruit-trees more powerful appliances are required.

Nixon's Climax nozzle is excellent for spraying clear liquids, but its use demands considerable power in the pumps.

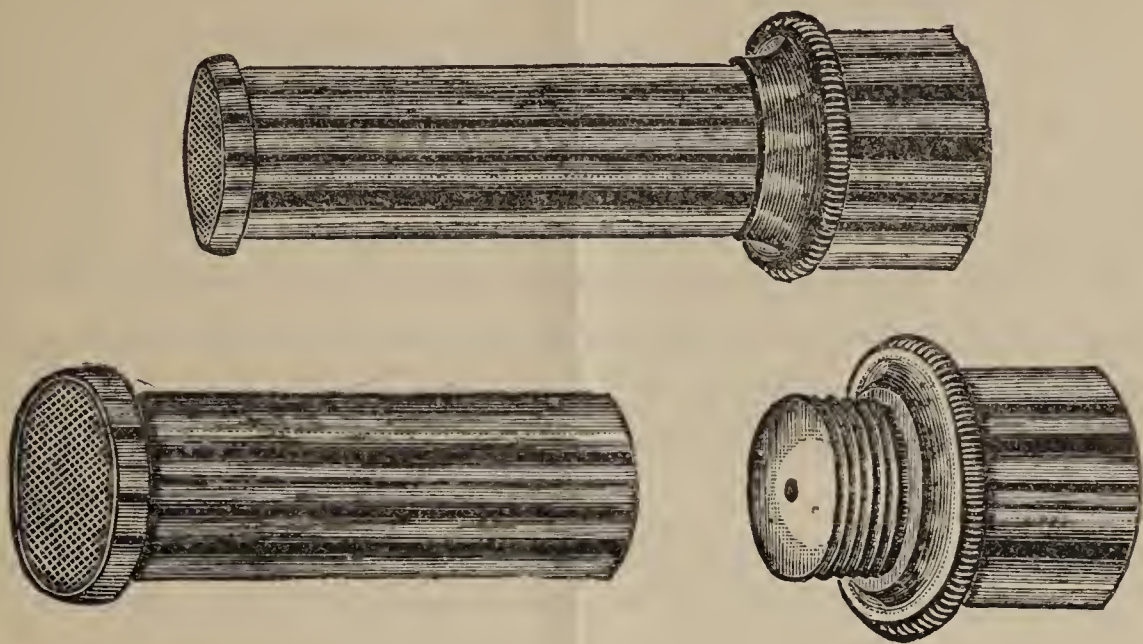


FIG. 1.—Nixon's Climax Nozzle.—This is made in three sizes, differing in size of jet and "no." of the gauze used to cover the top.

The Vermorel modification of the eddy chamber or cyclone nozzle is a most excellent pattern for both clear and pasty or thick liquids. The degorger combined with it renders the spraying of the latter possible.

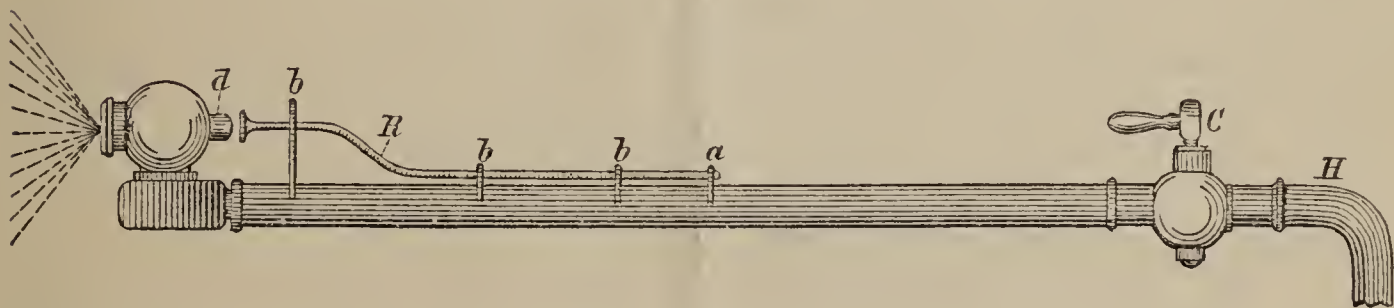


FIG. 2.—The Vermorel Nozzle with Lance.—The hose is attached to the lance at H. C., stop-cock. d, exposed end of the degorger; at the other end of the degorger is a pin which may be made to pass through the opening of the nozzle, clearing it when clogged. The degorger is pushed in by the rod R, sliding through the fixed bearings b, b, b. The force of liquids under pressure will bring it back into position.

LIQUIDS.

1. Simple solution of sulphate of copper.

(Comptes Rendus, Paris, October 5, 1885; Bull. 2, Bot. Div. U. S. Dept. of Agr., 1886, p. 89; Report of the Mycologist, 1886, p. 100; Circular No. 3, Sect. of Veg. Pathology, April, 1887.)

Dissolve 1 pound of pure sulphate of copper in 25 gallons of water.
For treatment of downy mildew and oïdium of the vine. For treatment of downy mildew and black-rot of the grape.

2. Simple solution of sulphate of copper.

(Diseases of Field and Garden crops, Smith, 1884, p. 261; Report of the Assistant Botanist, U. S. Dept. of Agr., 1885, p. 79; Report of the Kentucky Expr. Sta., 1887, p. 14; Bull. No. 3, Central Ex. Farm, Ottawa, Canada, p. 14.)

Simple solution in water, 5 to 8 pounds to 10 gallons.

For soaking grains previous to sowing to destroy the spores of smuts.

3. Copper mixture of Gironde, Bordeaux mixture.

(La Vigne Americaine, June, 1886, p. 193; Bull. 2, Bot. Div., U. S. Dept. of Agr., 1886, p. 15; report of the Mycologist, U. S. Dept. of Agr., 1886, p. 100; Circular No. 3, U. S. Dept. of Agr., April, 1887; Circular No. 4, U. S. Dept. of Agr., July, 1887; Le Mildiou, G. Patrigeon, 1887, p. 98; Traitement du Mildiou, Millardet, 1887, p. 35; Manuel Pratique pour le Traitement des Maladies de la Vigne, Viala and Ferrouillat, 1888, p. 26.)

Original formula.—Dissolve 16 pounds of sulphate of copper in 22 gallons of water, in another vessel slake 30 pounds of lime in 6 gallons of water. When the latter mixture has cooled it is slowly poured into the copper solution, care being taken to mix the fluids thoroughly by constant stirring. It is well to have this compound prepared some days before it is required for use. It should be well stirred before applying.

Numerous modifications in the preparation of this compound have been suggested, chiefly for the purpose of reducing the amount of copper.

A solution containing the ingredients in the following proportions has been recommended for general use:

Sulphate of copper	pounds..	4
Lime	do....	4
Water.....	gallons..	22

The copper is dissolved in 16 gallons of water, while the lime is slaked in 6 gallons. When cool the solutions are mixed as described above.

For treatment of mildew. For downy mildew and black-rot of the grape. For blight and rot of the tomato and potato.

4. Eau Celeste, Audouynaud process.

(Progrès Agricole et Viticole, March 28, 1886; Report of the Mycologist, 1886, p. 102; Circular No. 3, Sect. of Veg. Pathol. U. S. Dept. of Agr., April, 1887; Circular No. 4, Sect. of Veg. Pathol. U. S. Dept. of Agr., July, 1887; Sixth Report of the New York Experiment Station, 1887, p. 106; Le Développement et le Traitement du Mildiou et de L'Anthracnose, Millardet, 1887.)

Dissolve 1 pound of sulphate of copper in 2 gallons of hot water; when completely dissolved and the water has cooled, add $1\frac{1}{2}$ pints of commercial ammonia (strength 22° Baumé); when ready to use dilute to 22 gallons. The concentrated liquid should be kept in a keg or some wooden, earthen, or glass vessel.

For downy mildew. For treatment of downy mildew and black rot of the grape. For treatment of mildew and anthracnose. For blight and rot of the tomato and potato. For apple scab.

5. Eau Celeste, modified formula.

(Progrès Agricole et Viticole, July, 1887, p. 18; Etc.)

Sulphate of copper	pounds..	2
Carbonate of soda	do....	$2\frac{1}{2}$
Ammonia (22° Baumé)	pints..	$1\frac{1}{2}$
Water.....	gallons..	22

Dissolve the sulphate of copper in 2 gallons of hot water, in another vessel dissolve the carbonate of soda in a similar manner; mix the two solutions, and when all chemical reaction has ceased add the ammonia; then dilute to 22 gallons.

6. Solution of ammoniacal carbonate of copper.

(Progrès Agricole et Viticole, August, 1887, p. 114; Etc.)

Prepared as follows: Into a vessel having a capacity of two quarts or more pour one quart of ammonia (strength 22° Baumé), add 3 ounces carbonate of copper, stir rapidly for a moment and the carbonate of copper will dissolve in the ammonia, forming a very clear liquid. The concentrated liquid thus prepared may be kept indefinitely. For use, dilute to 22 gallons.

For peronospora of the vine.

7. Sulphate of iron.

(La Vigne Américaine, June, 1884, p. 181; Bull. 2, Bot. Div. U. S. Dept. of Agr., 1886, pp. 38 and 121; Report of Mycologist, U. S. Dept. of Agr., 1886, p. 114; Etc.)

Simple solution in water 4 to 8 pounds to the gallon, to be used only as a wash.

For anthracnose.

8. Chloride of iron.

According to Nature (vol. xxxvii) a very dilute solution of the above-named substance has been used with success in combating the coffee disease due to *Hemileia vastatrix*. This fungus is a member of the group *Uredineæ* (rusts), and it is said that the chloride of iron not only cures the disease, but also prevents its recurrence. The solution is applied to the under surface of the leaves by means of a pulverizator or spraying apparatus. Its sticky nature causes it to adhere for two months.

9. Skawinski's sulphate of iron and sulphuric acid solution.

(Traitements des Maladies de la Vigne, Viala et Ferrouillat, 1888, p. 84.)

Sulphate of iron	pounds..	110
Sulphuric acid (53°)	pints..	1½
Warm water	gallons..	22

“In order to avoid sputtering it is necessary to be very careful in pouring the sulphuric acid upon the crystals of iron sulphate, and not to add the warm water until after this operation. Besides, it is best to use sulphuric acid of only 53° Baumé, because it is less dangerous to handle. I am careful to use this mixture the same day and while warm, for when it becomes cold the sulphate of iron crystalizes and the solution has no longer the strength necessary in order to be efficacious.”

10. Sulphide of potassium, Liver of sulphur.

(Garden 1885, p. 379; Gardeners' Chronicle, 1885, Vol. XXIII., pp. 276, 352, 378; Vol. XXIV., p. 379; Bull. 2, Bot. Div. U. S. Dept. of Agr., 1886, p. 67; Report of the Mycologist U. S. Dept. of Agr., 1886, p. 121; sixth report of the New York Experiment Station 1887, pp. 348, 349, 350; Etc.)

Simple solution in water, $\frac{1}{4}$ to 1 ounce to the gallon.

For mildew in greenhouses. For mildew on roses. For oïdium and erinose of the vine. For orange-leaf scab. For celery-leaf blight. For pear and apple scab.

11. Solution of hyposulphite of soda.

(Report of the New York Experiment Station, 1885, pp. 231, 232; 1886, pp. 177, 178; 1887, pp. 99, 100; Report of the Mycologist U. S. Dept. of Agr., 1886, p. 120; Etc.)

Simple solution made by dissolving 1 pound of the soda in 10 gallons of water. Must be used as soon as prepared.

For apple scab. For celery-leaf blight. For orange-leaf scab.

12. Liquid Grison. Eau Grison.

(American Agriculturist, 1885, p. 295; Bull. No. 2, Bot. Div. U. S. Dept. of Agr., November, 1886, p. 26; Report of the Mycologist Sect. of Veg. Pathology, 1886, p. 21; Etc.)

Prepared by boiling 3 pounds each of flowers of sulphur and lime in 6 gallons of water until reduced to 2 gallons, when settled pour off the clear liquid and bottle it. When used, mix 1 part of the clear liquid in 100 parts water.

For mildew on grape vines. For powdery mildew of the vine.

13. Milk of lime.

(Bull. No. 2, Bot. Div. U. S. Dept. of Agr., 1886, p. 70; Report of the Mycologist Sect. of Veg. Path. U. S. Dept. of Agr., 1886, p. 100; Développement et le Traitement du Mildiou et de L'Anthracnose, Millardet, 1887; Etc.)

Simple solution in water, 2 to 6 parts lime to 100 parts water.

For peronospora of the vine. For anthracnose.

14. Phenic acid. Carbolic acid.

(La Vigne Americaine, July, 1884, p. 197; Journal de Agr. Pratique, p. 76, 1884; Etc.)

Simple solution in water one-half pint to 10 gallons.

For powdery mildew of the vine.

15. Phenic acid in solution diluted with soap-suds and glycerine.

(Report of Mycologist U. S. Dept. of Agr., 1886, p. 121.)

Soap-suds 10 gallons, glycerine 1 pound, carbolic acid one-half pint; mix thoroughly to form an emulsion.

For orange-leaf scab?

POWDERS.

16. Sulphur.

(Bull. No. 2, Bot. Div. U. S. Dept. of Agr., 1886, pp. 26, 27; Report of the Mycologist U. S. Dept. of Agr., 1886, p. 108; Etc.)

For grape mildew. For powdery mildew of the vine.

17. Sulphur and lime.

A mixture of sulphur and lime in equal parts by weight.

For treatment of anthracnose during the growing season.

18. Blight powder, Sulphated sulphur.

(Progrès Agricole et Viticole, 1887, p. 39; Report of the Mycologist U. S. Dept. Agr., 1886, p. 103; Circular No. 4, Section of Veg. Pathology, U. S. Dept. of Agr., July, 1887.)

Prepared by thoroughly mixing from 3 to 8 pounds of anhydrous sulphate of copper with 90 to 100 pounds of flowers of sulphur.

For simultaneous treatment of oïdium and the downy mildew. For downy mildew of the vine. For tomato and potato blight and rot.

19. Sulphatine, the Estève process.

(Bull. de Cent. Soc. de France, 1887, p. 316; Report of the Mycologist U. S. Dept. of Agr., 1886, p. 102; Circular No. —, U. S. Dept. of Agr., April, 1887; Circular No. 4, U. S. Dept. of Agr., July, 1887; Etc.)

Mix 2 pounds of anhydrous sulphate of copper with 20 pounds of flowers of sulphur and 2 pounds of air-slaked lime. The proportions may be varied.

For the treatment of mildew. For the treatment of the downy mildew and black rot of the grape. For the treatment of the tomato and potato for blight and rot.

20. Skawinski's powder.

(La Vigne Américaine, Nov., 1886; Report of the Mycologist U. S. Dept. of Agr., 1886, p. 104; Cours Complet de Viticulture, G. Foex, 1888, p. 485; Progrès Agricole et Viticole, Mar., 1888, p. 222; Etc.)

Mix 22 pounds of finely powdered sulphate of copper with 33 pounds of soot or alluvial earth and 165 pounds of coal dust.

For simultaneous treatment of oïdium and downy mildew of the vine. For treatment of mildew.

21. Sulfosteatite or cuprique steatite.

(Le Mildion, par Dr. G. Patrigeon, 1887, p. 134, Journal d'Agriculture Pratique, 1887, p. 768; Etc.)

An exceedingly fine bluish powder composed of steatite, or talc, and sulphate of copper, the proportion of the latter substance amounting to about 10 per cent. Very easily applied; considered the most adherent of all the powders.

For the treatment of mildew (*Peronospora*).

22. David's powder.

(Journal d'Agr. Pratique, Nov. 25, 1886; Report of the Mycologist U. S. Dept. of Agr., 1886, p. 102; Nouvelles Recherches sur le Développement et le Traitement du Mildion et de L'Anthracnose, Millardet, Feb., 1887, p. 22; Circular No. 3, Sect. of Veg. Pathol., U. S. Dept. Agr., April, 1887; Etc.)

Dissolve 4 pounds of sulphate of copper in the least possible amount of hot water, and slake 16 pounds of lime with the smallest quantity of water required. When the copper solution and slaked lime are completely cooled mix them together thoroughly; let the compound dry in the sun, crush and sift. Apply with a sulphuring bellows furnished with an outside receptacle for the powder. The copper coming in contact with the leather will soon destroy it.

For downy mildew. For downy mildew and black rot of the grape.
For mildew and anthracnose.

23. Podgehard's powder.

(Bull. Soc. Agr. Herault, France, 1886, p. 59; La Vigne Américaine, June, 1886, p. 193; Bull. 2, Bot. Div. U. S. Dept. of Agr., Nov., 1886, pp. 80, 81, 82: Report of the Mycologist U. S. Dept. of Agr., 1886, p. 101; Le Développement et le Traitement du Mildiou et de L'Anthracnose, Millardet, Feb., 1887; Etc.)

	Pounds.
Air-slaked lime	225
Sulphate of copper	45
Flowers of sulphur	20
Ashes	30

Dissolve the sulphate of copper in the water; when thoroughly dissolved pour the solution upon the lime, which is surrounded by the ashes to keep the liquid from spreading; after twenty-four hours add the sulphur, thoroughly mix the compound, ashes and all, and when dry sift through a sieve with meshes of one-eighth of one inch. This preparation may be made several months before it is required for use.

For the downy mildew of the vine. For the treatment of mildew and anthracnose.

WASHINGTON, D. C., April 25, 1888.